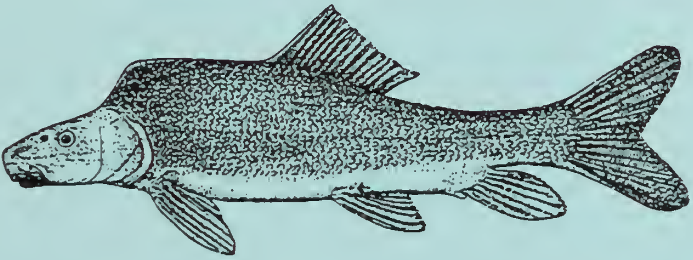
WRD Resource Room GLCA

Fish Management Plan



Glen Canyon National Recreation Area

ARIZONA GAME & FISH

State of Utah
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF WILDLIFE RESOURCES

NATIONAL PARK SERVICE
DEPARTMENT OF THE INTERIOR

April 1996

Digitized by the Internet Archive
in 2012 with funding from
LYRASIS Members and Sloan Foundation

http://archive.org/details/fishmanagementpl00nati

GLEN CANYON NATIONAL RECREATION AREA
UTAH/ARIZONA

FISH MANAGEMENT PLAN

APRIL 1996

UTAH DIVISION OF WILDLIFE RESOURCES
ARIZONA GAME AND FISH DEPARTMENT
THE NATIONAL PARK SERVICE

APPROVED BY:

DIRECTOR, UTAH DIVISION OF WILDLIFE RESOURCES	6-10-96 DATE
SUPERINTENDENT, GLEN CANYON NATIONAL RECREATION AREA	6-28-96 DATE
DIRECTOR, ARIZONA GAME AND FISH DEPARTMENT	8-8-96 DATE

TABLE OF CONTENTS

I. INTRODUCTION 1
BACKGROUND 2
PURPOSE AND NEED FOR THE PLAN 3
Objectives of the Plan 3
Objectives of Fish Management 3
HISTORY OF GLEN CANYON NRA 3
ISSUES AND CONCERNS 4

II. OVERVIEW OF MANAGEMENT POLICIES AND AUTHORITIES 5
RELATIONSHIP TO PLANNING DOCUMENTS 5
National Park Service 5
Utah Division of Wildlife Resources 5
Arizona Game and Fish Department 6
OTHER AUTHORITIES 6
National Park Service 6
Utah Division of Wildlife Resources 7
Arizona Game and Fish Department 7
Endangered Species Act (ESA) 7
Clean Water Act (1973) 8
Wild and Scenic Rivers Act 8
MOU Between Glen Canyon NRA and Utah Division of Wildlife 8
Executive Order 12962 8
RELATIONSHIP TO OTHER AGENCIES/GROUPS 8
U.S. Fish and Wildlife Service 8
Bureau of Reclamation 8
National Biological Service 9
Recovery Implementation Programs 9
Lake Powell Native Fish Work Group 9
Universities/contractors 9
Grand Canyon Adaptive Management Program 9
Canyonlands and other National Parks on the Colorado Plateau 10
Navajo Nation 10

III. GENERAL PHYSICAL AND BIOLOGICAL ENVIRONMENT 10
PHYSICAL ENVIRONMENT 10
Geography 10
Geology 10
Climate 11
Water Resources 11
BIOLOGICAL AND ECOLOGICAL RELATIONSHIPS 14
Pre-dam History of Ecosystem and Fishery 14
Post-dam History of Ecosystem and Fishery 14

IV. FISH MANAGEMENT PLANNING 17
FLOWING RIVERS 19
Status of rivers 19

        Goal for Rivers 20
        Flowing River Management Objectives 20
    INFLOWS 20
        Status of Inflows 20
        Inflow Goal 23
        Inflow Management Objectives 23
    LAKE POWELL 23
        Status of Lake Powell 23
        Lake Powell Goal 23
        Lake Powell Management Objectives 25
    LEES FERRY TAILWATER 25
        Status of Lees Ferry Tailwater 26
        Lees Ferry Tailwater Goal 26
        Lees Ferry Tailwater Management Objectives 26
    PERENNIAL/INTERMITTENT STREAMS 27
        Status of Fisheries in Streams 28
        Stream Goal 28
        Stream Management Objectives 28

V. PLAN IMPLEMENTATION 28
    PLAN REVIEW AND RENEWAL 28
    ANNUAL WORKPLAN MEETINGS 28
    WORKPLAN DEVELOPMENT 29
    WORKPLAN APPROVAL 29
    DATA SHARING 29

VI. EDUCATION/PUBLIC OUTREACH 29
    INTERPRETIVE PROGRAMS 29
    HOTLINE 29
    DISPLAYS AND BROCHURES 29
    VIDEOS 29
    PARTNERSHIP WITH SCHOOLS 29

APPENDIX A: STOCKING HISTORY OF LAKE POWELL, UTAH-ARIZONA, 1963-1995. 31

APPENDIX B: STOCKING HISTORY OF LEES FERRY TAILWATER 34

APPENDIX C: FIGURE 1 (MAP) GLEN CANYON NRA, INCLUDING LAKE POWELL AND MAJOR TRIBUTARIES 35

BIBLIOGRAPHY 38

I. INTRODUCTION

A. BACKGROUND - Glen Canyon National Recreation Area (NRA) includes Lake Powell, one of the Nation's most significant water resources. Encompassing nearly 2,000 miles of shoreline and over 180 miles in length, Lake Powell is the second largest reservoir in volume of water after Lake Mead. Lake Powell is an integrator of physical, chemical, and biological inputs from its vast watershed (111,700 square miles). Fishery managers within Glen Canyon NRA recognize that aquatic habitats within the Glen Canyon NRA boundary are an integral part of the larger Colorado River system. Dam operations alter and affect both upstream and downstream aquatic resources. Although altered by human control, impoundments such as Lake Powell support aquatic communities in which "natural" ecosystem processes continue. Water resources within Glen Canyon NRA support recreational fishing opportunities for the public and offer unique challenges and opportunities for fishery managers.

Impounded by Glen Canyon Dam, Lake Powell spans the Arizona-Utah border (Figure 1), and falls within the jurisdictions of several agencies, including the National Park Service (NPS), the states of Utah and Arizona, the Navajo Nation, and the U.S. Bureau of Reclamation (BOR). The U.S. Fish and Wildlife Service (USFWS), water developers, and other regional and local groups also have interests related to water and aquatic resources monitoring, management, and protection.

Other important waters within Glen Canyon NRA include flowing portions of the Colorado, Dirty Devil, Escalante, Paria, and San Juan rivers. The native fish community in these rivers has declined since the creation of dams. Four of the endemic "big river" fish which have been negatively impacted include the endangered Colorado squawfish (Ptychocheilus lucius), humpback chub (Gila cypha), bonytail (Gila elegans), and razorback sucker (Xyrauchen texanus). Recovery programs for these species focus primarily upon upstream riverine habitats, however, critical habitat reaches within the Glen Canyon NRA are occupied by some of these species. The inflow zone where rivers interface with the reservoir are used during certain stages in the life history of some of these endangered endemic Colorado River species.

Other native fish species also utilize habitats within Glen Canyon NRA. Roundtail chub (Gila robusta), flannelmouth sucker (Catostomus latipinnis), bluehead sucker (Catostomus discobolus), and speckled dace (Rhinichthys osculus) are native species found within Glen Canyon NRA that warrant management consideration. Maintaining native species as components of the aquatic community is part of preserving them as a natural legacy for future generations.

Currently, Lake Powell provides habitats for numerous species of introduced fish (nonnatives) which support outstanding recreational sport fishing opportunities. Anglers can experience the excitement of catching striped bass during a "striper boil", stalking large and smallmouth bass, and variety fishing for catfish, crappie, sunfish, and walleye. Rainbow trout in the Lees Ferry tailwater invite anglers from around the world. Providing a quality, sustainable recreational fishery in this spectacular setting is congruous with the NPS's recreational fishing program, "A Heritage of Fishing", as well as both Utah and Arizona's strategic plans and the mission statements of all signatory agencies. President Clinton directed Federal agencies to work together with states to develop comprehensive fish management plans within 1 year from when he signed Executive Order 12962 on Recreational Fisheries in June 1995.

B. PURPOSE AND NEED FOR THE PLAN - This Fish Management Plan (FMP) is designed for the purpose of long range planning and implementation of an integrated, interagency cooperative management effort related to fisheries issues within Glen Canyon NRA. A FMP is needed for Glen Canyon NRA because of the complex nature and ecological challenges created by Glen Canyon Dam and Lake Powell, which alter and affect both upstream and downstream aquatic communities and river processes. The FMP is needed to coordinate ongoing and future efforts of several agencies. The scope of this plan covers aquatic resources within the Glen Canyon NRA as related to fish.

This is a 5-year plan. It will identify long range goals, management objectives, and information needs. Annual research priorities, specific tasks, staffing, and budgetary requirements will be specified through development of annual workplans (see section V. Plan Implementation).

This FMP provides a framework for resource managers to meet and discuss issues, identify roles, establish protocols, and resolve conflicts, while at the same time expanding expertise and resources available to each agency. The plan identifies issues, goals, and objectives related to fish as identified in the recreation area's General Management Plan (GMP), Resource Management Plan (RMP), and the Utah Division of Wildlife Resources (UDWR) and Arizona Game and Fish Department (AGFD) strategic plans. The development of this FMP was called for in the 1993 Memorandum of Understanding between UDWR and the NPS at Glen Canyon NRA.

This FMP incorporates the missions of the National Park Service and the states of Utah and Arizona in relation to management of fishery resources. Fundamental to this plan is the belief that with proper management and planning, Glen Canyon NRA can provide for both an outstanding recreational sport fishery and preservation of native fish species.

1. Objectives of the Plan

   a. Provide a mechanism for formal coordination and cooperation between the National Park Service and the states of Utah and Arizona for fish management planning and activities.

   b. Identify concerns and issues related to fish management.

   c. Promote and enhance interagency cooperation to maximize efficiency and expertise in understanding aquatic processes.

2. Objectives of Fish Management

   a. Protect the integrity of aquatic habitats and water quality.

   b. Protect and restore native fish species within suitable habitats in Glen Canyon NRA.

   c. Promote and provide quality recreational fishing opportunities in Glen Canyon NRA.

C. HISTORY OF GLEN CANYON NRA - Glen Canyon Dam was authorized by Congress in 1956 to provide water storage in the Upper Colorado River Basin. The result was the creation of Lake Powell.

Preimpoundment investigations were conducted as early as 1959 by UDWR. UDWR joined AGFD and cooperatively managed the fisheries in the new impoundment until 1970 when Utah assumed lead responsibility for the reservoir. Since 1970, UDWR has acted as the primary fisheries management agency for Lake Powell.

NPS presence occurred in 1972 when Glen Canyon NRA was established as a unit of the National Park Service by Public Law (92-593) "to provide for public outdoor recreation use and enjoyment of Lake Powell and lands adjacent thereto...and to preserve the scenic, scientific, and historic features contributing to public enjoyment of the area...". This legislation specifically mandates recreational fishing.

D. ISSUES AND CONCERNS RELATED TO FISH RESOURCES WITHIN GLEN CANYON NRA

The following issues have been identified as important to the long-term protection and management of fish communities and sport fisheries within Glen Canyon NRA.

1. The effects of dam operation on fisheries are not well understood within Glen Canyon NRA. Alteration of flows, sediment transport, nutrients, temperature, and lake elevation all affect fish, yet biological input into dam operations has not always been considered in the decision making process.

    a. Impacts to endangered fish below Glen Canyon Dam are a major consideration of the Glen Canyon Dam Environmental Impact Statement (EIS), and how preferred alternative flows from dam operations will affect fish needs assessment.

    b. Impacts from operation of Glen Canyon Dam on critical habitat of inflow reaches have not been assessed.

    c. The effects of raising the spillway gates 4.5 feet as proposed in the Glen Canyon Dam EIS have not been evaluated.

    d. Operation of upstream dams including Flaming Gorge Dam and Navajo Dam affect endangered fishes within Glen Canyon NRA as the receiving system. Assessment of how the manipulation of those dam operations impact fishery resources within Glen Canyon is needed.

    e. Impacts from dam operations including an experimental spike flow hydrography, construction of selective withdrawal structures, and winter low flows in the San Juan River are unknown.

2. Reasons for continued declines of threatened and endangered endemic fishes and other native species of the Colorado River within Glen Canyon NRA need to be identified and mitigated.

3. There is a general lack of information about native species within Glen Canyon NRA including status, habitat needs, and the effects of competition/predation with nonnatives.

4. Differences and conflicts in state and Federal laws and regulations affecting fishery resources within Glen Canyon NRA need resolution.

5. Trace elements and contaminants in fish tissues and the aquatic food web are of concern due to implications to long lived fishes and the angling public.

6. NPS is not formally involved in Recovery Implementation Programs (RIPs) and critical habitats within the Glen Canyon NRA are largely unstudied.

7. Invading organisms, parasites and disease threaten aquatic systems and require protective measures.

8. Maintaining a balanced, healthy fish community is necessary to provide quality angling opportunities with good quality harvest.

9. There has been a lack of federal involvement in a coordinated interagency attempt to promote recreational fishing.

10. There is a need to develop a public education and outreach program about fishery issues.

II. OVERVIEW OF MANAGEMENT POLICIES AND AUTHORITIES

A. RELATIONSHIP TO PLANNING DOCUMENTS

1. National Park Service

a. Resource Management Plan (RMP) (1991): The RMP documents the natural and cultural resources of Glen Canyon NRA, describes and evaluates the current management activities, proposes specific actions, identifies deficiencies, along with recommendations, to address areas of concern.

b. Statement for Management (1991): This document provides a current inventory of the recreation area's condition, and analysis of problems. The need to develop a cooperative fisheries management plan is identified as a priority management objective in this document.

2. Utah Division of Wildlife Resources

a. Strategic Plan (1992): Utah's strategic plan was developed for the benefit of wildlife, focusing on preserving Utah's unique fish and wildlife heritage. It presents the 5 year management goals and objectives for all protected wildlife in Utah. It identifies problems and specifies strategies to overcome them. The plan provides strong focus for UDWR work, year-to-year priorities and allocation of resources.

b. Lake Powell Water Management Plan: This plan states management goals and objectives for Lake Powell sport fishery including sport fish harvest goals.

3. Arizona Game and Fish Department

WILDLIFE 2000 Strategic Plan: This plan implements a strategy of cooperation with state and federal agencies and local governments to meet the mission. It includes a sportfish strategic plan that describes the current supply and demand and future demands. It also includes a nongame and endangered wildlife plan.

B. OTHER AUTHORITIES

1. National Park Service: NPS is the federal land managing agency within Glen Canyon NRA. Other NPS units form a corridor along the Colorado River, and the NPS is the resource manager for a portion of designated critical habitat for endangered fish.

a. Organic Act of 1916: The National Park Service has as its agency mandate to "conserve the scenery and the natural and historic objects and wildlife therein and to provide for the enjoyment of the same in such a manner and by such means as will leave them unimpaired for the enjoyment of future generations".

b. NPS Fishery Management Policy (NPS-77, 1988): Fishery Management Policy states:

"Reservoirs, and in some cases channelized or otherwise manipulated rivers and streams, represent altered environments that may reduce populations of some native species of fish and encourage others..." The new ecological environments and niches created by the alteration of natural waterways may be most successfully filled by exotic fish species; nevertheless, management activities will give precedence to native fish species over exotics wherever native species are adaptable to the altered environment... (4:8)"

c. Redwood National Park Act (P.L.90-545): This act includes both park specific and system-wide provisions, such as protection of the watershed to reduce upstream sedimentation impacts, rehabilitation of past timber harvested areas, and increased economic assistance in the effected local community. Congress reaffirms and directs that the promotion and regulation of the National Park system be consistent with the Organic act of 1916, and that the protection, management and administration of these areas shall not allow derogation of values and purposes or the resources for which the areas were established.

2. Utah Division of Wildlife Resources: UDWR is the wildlife management authority for the State of Utah. Since most of Lake Powell is in Utah, UDWR is the major wildlife manager, cooperator, and signatory with NPS and AGFD on this plan.

a. Mission Statement: "The mission of the Division of Wildlife Resources is to assure the future of the protected wildlife for its intrinsic, scientific, educational and recreational values through protection, propagation, management, conservation and distribution throughout the state."

b. Utah Code (Section 23-14-1): UDWR is the wildlife authority within the State of Utah. UDWR is charged with the responsibility to protect, propagate, manage, conserve, and distribute protected wildlife throughout the state. UDWR is also granted jurisdiction over all wildlife in the state, including, but not limited to, wildlife on public or private land and waters within the state (Section 23-15-2 of the Utah Code).

3. Arizona Game and Fish Department: AGFD is the regulatory agency for fish and wildlife resources within Arizona and lead on fisheries in the Glen Canyon Dam tailwater reach; they are cooperators and signatory with NPS and UDWR on this plan.

AGFD Mission Statement: "To conserve, enhance, and restore Arizona's diverse wildlife resources and habitats through aggressive protection and management programs, to provide wildlife resources, and safe watercraft and off-highway recreation for the enjoyment, appreciation and use by present and future generations".

4. Endangered Species Act (ESA): The purpose of the Endangered Species Act is to protect the nation's fish, wildlife and plant species that are threatened with extinction. The Act is administered by the U.S. Fish and Wildlife Service. Section 6 of the Act involves the cooperation with the states. Federal agencies and their actions are to further the purpose of conserving endangered species, as directed in Section 7 of the Act. Section 7 further requires that federally funded or

authorized projects or actions do not jeopardize the continued existence of endangered species or result in adverse modification of critical habitat.

5. Clean Water Act (1973): Protects the Nation's water resources and identifies the need to maintain the integrity of water acceptable for aquatic life uses, including fishery resources.

6. Wild and Scenic Rivers Act: (47 FR 39454,1982) Specifies the process used to study rivers for inclusion in the National Wild and Scenic Rivers system. To be eligible, the river or segment must be free flowing and exhibit outstandingly remarkable natural, cultural, or resource values. Portions of 29 rivers and streams in the NRA exhibit these values.

7. MOU Between Glen Canyon NRA and Utah Division of Wildlife: Signed in 1993, both agencies mutually agreed to work cooperatively in fish and wildlife management activities. Specific statements include: development of joint fish and wildlife management plan(s), annual coordination meetings, exchange of permits by each agency for collecting wildlife, third party proposal submission review by both agencies, collections management, data exchange and joint participation in field activities. The FMP addresses these topics as related to fish management.

8. Executive Order 12962 on Recreational Fisheries: Signed in June 1995, federal agencies are to develop comprehensive recreational fishing plans, including coordination among other state and federal agencies to promote partnerships for expanding fishing opportunities and stewardship.

C. RELATIONSHIP TO OTHER AGENCIES/GROUPS

1. U.S. Fish and Wildlife Service (USFWS): All work related to threatened and endangered (T&E) species must be coordinated with USFWS, the agency charged with administering the ESA. Annual workplans and activities related to T&E species will be submitted to USFWS for required permits.

2. Bureau of Reclamation (BOR): BOR is responsible for dam operation and, therefore, controls lake elevation, and river discharge. BOR prepared an Environmental Impact Statement (EIS) to determine potential impacts of dam operation on T&E species and downstream resources through funding Glen Canyon Environmental Studies (GCES). Dam operation or future actions that potentially impact fishery resources include adding a

selective withdrawal structure, raising full pool lake elevation by 4.5 feet, and high discharge releases. BOR is involved in transition monitoring and participates formally in Recovery Implementation Programs (RIP).

3. National Biological Service (NBS): NBS conducts research and monitoring related to assessment of organisms, populations and condition of biological resources. Within Glen Canyon NRA, NBS has responded to NPS requests for assistance by active involvement in fisheries programs.

4. Recovery Implementation Programs (RIPs): RIPs have been formed as interagency committees to help prevent extinction of endangered fishes. RIPs were formed as a result of a USFWS determination that proposed federal action(s) would jeopardize the continued existence of endangered species. Ongoing recovery efforts focus on endemic fish populations in the Colorado and San Juan rivers and emphasize recovery of endangered species by establishing self-sustaining populations, particularly targeting free flowing river reaches. The Upper Colorado River Basin RIP focuses on the upstream Colorado River and tributaries, while the San Juan RIP focuses on San Juan River habitats and fish to address recovery of threatened and endangered fishes above Lake Powell. Critical Habitat reaches within Glen Canyon NRA have not been entirely included in RIP studies. Proposals related to endangered fishes are submitted for potential RIP funding. It is the intent of NPS and UDWR to cooperate with recovery efforts and incorporate the RIP guidelines into fishery efforts within the Glen Canyon NRA.

5. Lake Powell Native Fish Work Group (NFWG): Formed in 1993 at the invitation of NPS, this group includes fishery biologists from NPS, NBS, USFWS, BOR, state agencies, tribes, academia and the private sector. Meetings are held annually for the purpose of coordination, review, and expanding interagency information transfer, partnerships and expertise related to native fish issues.

6. Universities/contractors: Fishery investigations may be conducted by universities or independent consulting firms through contract with the NPS, UDWR, AGFD or other funding sources. Proposals must be submitted and permits obtained in compliance with guidelines.

7. Grand Canyon Adaptive Management Program (AMP): Related to the Grand Canyon Protection Act and a result of the Glen Canyon Dam EIS, the AMP will implement a long-term monitoring of effects of dam operation on resources within Grand Canyon National Park and Glen Canyon NRA.

8. Canyonlands and other National Parks on the Colorado Plateau: Park units along the Colorado River work cooperatively to investigate and understand how resources and processes transcend park boundaries. NPS units will coordinate, exchange information, and share resources and expertise for effective fish management among park units along Colorado River.

9. Navajo Nation: The Navajo Reservation boundary lies to the south of Glen Canyon NRA, sharing a common boundary at elevation 3720 feet. Navajo Nation representatives participate in RIPs and NFWG.

III. GENERAL PHYSICAL AND BIOLOGICAL ENVIRONMENT

A. PHYSICAL ENVIRONMENT

1. Geography: Glen Canyon NRA is centrally located in the Colorado River Basin in southeastern Utah and northern Arizona. Lake Powell covers 255 square miles and drains a watershed of 111,700 square miles. The watershed is extremely varied in ecosystem type, ranging from high alpine mountains in Colorado and Utah to arid deserts and canyons of the Colorado Plateau. The Upper Colorado River Basin drains highly erodible soils in arid to semi-arid climate. The four main tributaries into Lake Powell include the Colorado, San Juan, Dirty Devil, and Escalante rivers. A fifth tributary, the Paria River, enters the Colorado River 15 miles below Glen Canyon Dam, at the boundary of Glen Canyon NRA and Grand Canyon National Park.

2. Geology: The recreation area consists of highly dissected plateaus that create a maze of deep canyons with nearly vertical walls and flat topped mesas characteristic of the Colorado Plateau. Surface stratigraphy includes outcrops of rock that range in age from Pennsylvanian to Cretaceous. Permian and Pennsylvanian rocks are exposed in the Cataract and San Juan canyons. Cretaceous rocks are present in the eastern part of the Kaiparowits Plateau while marine deposition occurred during the Permian, Triassic, Jurassic, and Cretaceous Periods. The Navajo and Wingate sandstones that are extensively found around Lake Powell originated from wind blown sands deposited between the second and third occurrences of the inland seas. During Late Cenozoic period, volcanic activity created lava flows in the Grand Canyon that formed natural dams making temporary lakes in the Glen Canyon vicinity. Therefore, at some point during the evolution of the endemic Colorado River fishes, they may have survived and adapted to lake environments.

3. Climate: Glen Canyon NRA is classified as semi-arid to arid; annual rainfall ranges between 6 to 10 inches. High plateaus typically receive more rainfall than canyon bottoms. Summer thunderstorms are brief, intense and can cause flash flooding. March, August, and September are generally the wettest months, June is the driest. Evaporation greatly exceeds precipitation during all but winter months. The resulting loss from Lake Powell approximates 500,000 acre feet per year.

4. Water Resources: Prior to impoundment, the Colorado River flowing through Glen Canyon was a large, wide river prone to huge spring floods (80,000 to 300,000 cubic feet per second or cfs) which gave way to smaller, steady flows (3,000 cfs) in summer and winter. The smaller base flows were contained in the larger flood plain created by spring floods, giving the appearance of a shallow and turbid water course. The wide river was warmed rapidly by the summer sun, with peak temperatures nearing 80 F. Temperatures in the winter were near freezing, creating a wide annual temperature variance and making a harsh environment for wildlife living in the aquatic ecosystem. The river alternated between turbulent rapids cascading through narrow canyon sections with steep gradients, and long gentle runs and riffles in more open canyon sections (such as in Glen Canyon) with gentle gradients. Soils common to the area were constantly transported, being picked up by high flows and redistributed by lower flows.

After completion of Glen Canyon Dam, water releases were dependent on power production needs. The law of the river, including compacts and treaties, requires the annual release of 8.23 million acre feet (maf) of water through the dam. Daily releases depend on power generation needs which are greater during the day than at night, and higher during seasons of high power use, such as warm summer days and cold winter nights. Interim flow restrictions call for operation of base flow near 8,000 cfs to maximum flow of 20,000 cfs. Post dam water management regime eliminated spring floods and increased summer and winter flows.

Tributaries join the Colorado River within Glen Canyon NRA. The largest tributary is the San Juan River. Average discharge between 1914 and 1986 was 2,577 cfs. Highest flow ever recorded was 70,000 cfs. Zero flow was recorded twice in the 1930's. The historic flow regime of the San Juan was similar to that of the Colorado, only on a smaller scale. Spring floods produced large volumes of water which then receded into modest base flows. Since the completion of Navajo Dam in 1962, there has been a fairly stable output, averaging 2,500 cfs, within the range of 500-12,000 cfs.

The Dirty Devil River enters Lake Powell near Hite and adds a mean annual 99 cfs flow. The river is named for the heavy amount of suspended sediment attained in its journey through highly erodible soils. Peak flows generally occur in March and low flows are experienced in July. Daily flows range between 0-14,000 cfs. The input is quite steady within the range of 50-250 cfs.

The Escalante River has not been controlled by dams but some water is used seasonally for irrigation needs. Average inflow was 10 cfs for water years 1973-1994, with mean annual variation between 1.5 to 30.7 cfs. Mean daily flows ranged between 0.7 and 270 cfs, with peak flows in March and low flows in July.

The Paria River enters Glen Canyon NRA at Lees Ferry, downstream from Glen Canyon Dam and below the 15 mile trophy trout tailwater. Average flow is 2 cfs of silt laden water that joins with the clear, cold Colorado River tailwater at Lees Ferry and adds the first suspended sediment load back into the system below the dam.

The completion of Glen Canyon Dam in 1963 formed a new reservoir that eventually backed up some 186 miles behind Glen Canyon Dam. Within Glen Canyon NRA, water resources are grouped into the following habitat types:

a. Flowing rivers: River reaches exhibiting current offer habitat and conditions most similar to the river system prior to control by impoundments. The flood-prone, often turbulent, turbid Colorado River above Glen Canyon NRA still offers river habitat somewhat resembling that found prior to impoundment and development of the Colorado River. Native species may have some preference or adaptations to survive in flowing rivers, however, even the flowing portion of controlled rivers now exhibit alterations in many conditions such as: temperature, hydrography, and sediment and debris transport compared with historical pre-dam conditions. Flowing river reaches on the Colorado, San Juan, Dirty Devil and Escalante rivers are maintained above Lake Powell's full pool elevation of 3700 feet, and depending upon lake elevation, these flowing reaches can extend many miles in the Glen Canyon NRA.

b. Inflows: The inflow areas are artificially created areas formed as a result of the backing up of water after completion of the dam. Inflows are transition zones where river currents meet the lake. The estuary-like inflow area is characterized by turbidity, high productivity, and abundant fish life. The inflow is defined as that area where river current slows and then dissipates into the calm, flat water of the lake. There is often a sand or silt bar associated with the plunge point where the river enters the lake. The inflow area is transitory, moving up and downstream in response to changes in lake elevation. Hydraulic processes operating on silt deposits left by a receding lake form backwaters and habitats that may not have been present in the historic river channel, but which are utilized by early life stages of both native fish and sport fish.

c. Lake Powell: Lake Powell is a warm meromictic lake with a high degree of thermal and chemical stratification. It has a surface area that covers 255 square miles and contains up to 27 million acre feet of water. At full pool, depth of the reservoir near the dam is 561 feet. The thermocline changes seasonally, but below approximately 150 feet deep, the hypolimnion is consistently maintained due to thermal and chemical properties. Lake Powell exhibits a trophic gradient from the shallow productive inflows where nutrients and sediments are delivered by rivers, to the nutrient poor clear water by the dam. This type of trophic gradient exists in each dendritic arm of the lake, as well as the main river channels. As the reservoir gradually shallows moving uplake from the dam, the depth and extent of the thermocline and hypolimnion change. Lake elevation can change drastically year to year depending upon snowmelt and runoff. Recent information suggests hydraulic processes can deliver the spring runoff plume at a mid-depth extending the entire length of the lake. The clear water reservoir offers habitat beneficial to the proliferation of nonnative fish. Generally, the reservoir is oligotrophic; deep, clear, and low in nutrient and chlorophyll abundance.

d. Lees Ferry Tailwater: Water exits Lake Powell from the Glen Canyon Dam penstocks deep in the reservoir at elevation 3470 feet, creating a cold tailwater with a constant temperature near 46° F. The tailwater favors cold water species, like rainbow trout, which were not previously found in this reach of the Colorado River. The cold temperatures, coupled with the dam penstocks, limit fish movement downstream. Lake plankton is transported downstream to add to the food chain in the tailwater.

e. Perennial/intermittent streams: Many side canyons contain springs and streams which may offer habitats for fish. Inventories of these habitats will be required before their true importance is known.

B. BIOLOGICAL AND ECOLOGICAL RELATIONSHIPS

1. Pre-dam History of Ecosystem and Fishery: Specially adapted native fish prospered in the harsh Colorado River environment. Razorback sucker, Colorado squawfish, flannelmouth sucker, bluehead sucker, and two or three species of chub (Gila spp) were commonly found in the river. Commercial fisheries were supported by "white salmon" (Colorado squawfish) and razorback sucker. Some nonnative fishes were present in the river flowing through Glen Canyon but, with the exception of carp and channel catfish, most were confined to backwaters, side channels and small perennial tributaries. Plains killifish, mosquitofish, fathead minnow, largemouth bass, bluegill, black bullhead, and green sunfish were reported in preimpoundment fish surveys. Before 1960 vehicle access to Glen Canyon was limited, except an unpaved road to Lees Ferry. Angling was confined to this access point, unless by the occasional rafters as they floated the rivers.

2. Post-dam History of Ecosystem and Fishery: Closure of Glen Canyon Dam in 1963 began filling Lake Powell and created a new environment that drastically altered the habitat used by fish. The warm, shallow river gave way to a clear, deep, thermally stratified reservoir. Nonnative species became established by intentional and unintentional introductions (Appendix A.). Water released from the dam created cold water habitat which was stocked with trout. Largemouth bass and crappie populations were stocked initially and subsequently proliferated to provide the bulk of the sport fisheries in the filling reservoir. Both species have declined in recent years due to lack of brush shelter for young fish. Filling, fluctuation and aging of the reservoir resulted in changing habitat that favored different species. The filling reservoir had ample terrestrial vegetation that became great fish habitat when inundated by each succeeding spring flood. Centrarchids that use vegetation (largemouth bass, crappie, bluegill) proliferated under these conditions. But when the lake filled and subsequently declined, the brush was gone and brush loving fish declined. They were replaced by fish that could use the remaining ubiquitous rocky structure and open water more effectively. The habitat change led to the introduction of smallmouth bass, which is presently one of two dominant sport fish in the reservoir.

Threadfin shad (Dorosoma petenense) were introduced by UDWR into Wahweap Bay, Lake Powell in June 1968, to provide additional forage base. Approximately 90 percent of the original plant were young-of-the-year (yoy). Early sampling revealed that shad had spawned their first summer and spread to Halls Crossing, 73 miles uplake, by the summer of 1969. Shad were found reservoir-wide by the summer of 1970. Threadfin shad quickly became the predominant food item of all major game species in Lake Powell.

Striped bass (Morone saxatilis), an anadromous marine species originating on the Atlantic coast, were stocked into Lake Powell between 1974-1979. Information available at that time did not predict that striped bass could reproduce in sufficient numbers to maintain a recreational fishery in the freshwater reservoir without supplemental stocking. However, unprecedented natural reproduction and survival of striped bass allowed them to become the most numerous sports fish and dominate the fish community of Lake Powell.

Striped bass introduced into Lake Powell utilized the dense pelagic shad population. Threadfin shad numbers subsequently declined due to predation from striped bass. Low shad density caused striped bass condition to decline and resulted in starvation and reduction of striped bass. Less striped bass predation allowed shad to recover. This classic predator-prey cycle fluctuated wildly in the 1980's and still occurs within narrower parameters. Maintaining a balance of these two species is imperative for the overall quality of the sport fishery.

Other species now common in the reservoir (walleye, bluegill, green sunfish, carp and channel catfish) developed from stock present in the river system when the dam was closed. Nonnative fish living in the river that could not cope with the altered reservoir environment include fathead minnow, mosquitofish, and plains killifish. These fish are still present in the recreation area but are found mainly in the river reaches, inflows, and small perennial tributaries. Red shiner established a marginal reservoir population but are found much more often in the flowing water than in the lake.

Native fish species were displaced by habitat loss and alteration, as well as competition/predation with introduced nonnative fishes. Bonytail is the native species believed to be in the most peril of imminent extinction because they are virtually eliminated in the upper basin. In the upper basin, less than ten confirmed bonytails have been caught in the last 15 years. Bonytail were reported in Lake Powell soon after closure of Glen Canyon Dam, however, annual gill-net surveys conducted by UDWR have failed to produce any bonytail in the last 20 years.

The last known bonytail taken from Lake Powell was in May 1985 by an angler near Wahweap Marina.

After Glen Canyon Dam started backing up the waters of the Colorado River, Colorado squawfish became part of the fish fauna of Lake Powell. Since 1963, squawfish in Lake Powell have been declining. There have been no reports of squawfish in the lake since 1977. Before that, squawfish were reported to have been taken by anglers and in annual gill-net surveys conducted by UDWR. Colorado squawfish are believed to still inhabit the inflow area of the Colorado River. Young-of-the-year squawfish have recently been found in both the San Juan and Colorado River inflow areas of Lake Powell.

Very few humpback chubs have been found in Lake Powell. Annual gill-netting surveys conducted by UDWR have captured only three humpback chubs within Lake Powell in the last 20 years (1 in 1972 and 2 in 1975). It is presumed that humpback chubs are not present in the lake at this time, however, unidentified Gila species were collected by seines and light traps by BIO/WEST in the Colorado inflow. There are currently no reports of large numbers of humpback chubs in any of the other Colorado River impoundments.

Small numbers of razorback suckers have persisted in Lake Powell since the closure of the Glen Canyon Dam. From 1971 to 1991, eight razorback suckers have been caught throughout Lake Powell by UDWR in annual gill netting surveys. Inflows of the San Juan, Dirty Devil, and Colorado rivers are areas that hold larger numbers of fish. In 1987, the BOR and UDWR captured, tagged, and released 12 razorback suckers in the inflow of the San Juan River. The next year four more were caught with six recaptures. Additional efforts produced 14 razorbacks of which 11 were removed for broodstock. Similar numbers have been observed by researchers in Dirty Devil and Colorado River inflows.

Flannelmouth suckers are relatively uncommon in lakes and reservoirs, however, they have persisted in low numbers in Lake Powell. Flannelmouth suckers are probably the only native fish to inhabit the main body of Lake Powell in detectable numbers. Annual gill-net surveys conducted by UDWR have consistently produced flannelmouth suckers. However, there has been a declining trend in the population. At this time, reproductive recruitment has not been documented in Lake Powell. Flannelmouth suckers are found in the flowing Colorado, Escalante, Dirty Devil, and San Juan rivers and inflow zones. Flannelmouth suckers are also found below the dam in the Lees Ferry reach. The confluence of the Paria River provides important spawning habitat for flannelmouths below the dam and in the Grand Canyon.

AGFD began stocking rainbow trout below the dam in 1964. They introduced aquatic food organisms, amphipods commonly called scuds (Gammarus sp.), in 1968 to provide forage in the newly created tailwater. By 1977 trout over 3.5 pounds were frequently being harvested and trophies over 10 pounds were taken regularly. The large fish gained national notoriety for Lees Ferry. Angling pressure increased dramatically as the media spread the word about this new trout fishery. Increased angling pressure decreased average fish size and total numbers in the river. AGFD responded to the increase in angling pressure by reducing the limit from 10 to 4 fish, restricting fishing method to artificial lures only and requiring immediate kill or release of any fish taken. Despite these restrictive regulations, average size of fish caught continued to decline. Fluctuations in water level associated with hydroelectric peaking power caused concerns among anglers about stranding of spawning fish and eggs, impacts to the food base, and angler access. These concerns were incorporated into the Glen Canyon Environmental Studies (GCES), however, high flows and spills from 1983-1986 confounded evaluation of the impacts of fluctuating flows. Between 1980-1984, anglers voiced increasing concern over the decline in the fishery, in particular the declining size of fish. During this time, angler pressure had increased five times the level experienced in 1977. In 1990 a slot limit protecting all fish between 16-22 inches was incorporated and the limit was decreased to two fish. The slot limit increased trout biomass at the same time that phase II of GCES called for low river flows that dried portions of the river bed and reduced the trout food supply. Trout were stressed by the reduction of the food base and infestation by a common nematode resulting in decline in physical condition. Trout either became thin or died of starvation as the nematode interfered with digestion. The amount of water and flow regime released from the dam was demonstrated to have an impact on the Lees Ferry trout fishery. As the discharge increased and daily fluctuations were restricted, a more abundant food base developed. The skinny fish were eliminated by harvest or natural causes and the fishery is once again healthy and robust.

IV. FISH MANAGEMENT PLANNING

Within Glen Canyon NRA, each of the different habitat types (flowing rivers, inflows, Lake Powell, Lees Ferry tailwater and streams) favors a different complement of fish species (Table 1). In this section of the FMP, habitat types within the recreation area are described, along with the status of fisheries in each area. Management goals that conform to each of the various sets

Table 1. **FISH SPECIES AND DISTRIBUTION IN GLEN CANYON NRA**

SPECIES	RELATIVE ABUNDANCE	HABITAT TYPE	ORIGIN
Threadfin shad	COMMON,(population cycles annually)	Lake	Introduced forage fish
Smallmouth bass	ABUNDANT	Lake	Introduced sport fish
Striped bass	ABUNDANT	Lake	Introduced sport fish
Largemouth bass	COMMON	Lake	Introduced sport fish
Black crappie	RARE (common some years)	Lake	Introduced sport fish
Channel catfish	COMMON	Lake	Invading sport fish
Walleye	COMMON	Lake	Invading sport fish
Rainbow trout	COMMON	Tailwater rare in lake	Introduced sport fish
Northern pike	RARE	Hite area, inflow	Invading sport fish
Bluegill	ABUNDANT	Lake	Invading sport fish
Green sunfish	ABUNDANT	Lake	Invading fish
Yellow/black bullhead	COMMON	San Juan and Colorado inflow	Invading sport fish
Red shiner	COMMON	Lake, rivers, and inflows	Invading forage fish
Carp	ABUNDANT	Lake	Invading fish
Razorback sucker	RARE, (Endangered)	San Juan and Colorado inflow	Native to Colorado River
Colorado Squawfish	RARE, (Endangered)	Colorado River and San Juan inflow	Native to Colorado River
Humpback chub	RARE, (Endangered)	Cataract Canyon, Little Colorado River	Native to Colorado River
Bonytail	RARE, (Endangered)	Cataract Canyon	Native to Colorado River
Flannelmouth sucker	RARE	Lake,inflows, rivers,tailwater	Native to Colorado River
Bluehead sucker	RARE	Rivers, Inflows, tailwater	Native to Colorado River
Roundtail chub	RARE	Rivers, inflows	Native to Colorado River
Fathead minnow	ABUNDANT	Rivers, inflows	Invading forage fish
Mosquito fish	ABUNDANT	Inflows, rivers	Invading forage fish
Speckled dace	COMMON	Rivers & Inflows,stream	Native to Colorado River

of habitat and species are presented, then management objectives are identified to achieve the goal.

A. FLOWING RIVERS

1. Status of rivers: Native fishes remain a component of the fish community in flowing river reaches within Glen Canyon NRA. Nonnative fish do not thrive in harsh spring flood conditions. These are the very conditions that have been controlled by water development upstream from the Glen Canyon NRA. Although surveys of the river reaches within the NRA are incomplete, native fishes numbers are low and the listing of four endemic species as endangered illustrates the severity and urgency of the problem.

The four endangered fishes are generally considered long-lived species, and some are known to migrate great distances to spawn. Larvae of these species also drift long distances in river current until they settle in backwaters or slackwater nursery habitats.

Biocontaminants have potential detrimental impacts to fisheries. Naturally occurring trace elements, and trace elements from irrigation return flows, enter the food chain in plankton then bioaccumulate within organisms and biomagnify up the food chain. Long-lived species and top predators tend to concentrate some elements to levels that could negatively affect survival or reproduction.

Causes for decline of native fish in the rivers are not fully understood, but could include loss and change of habitat, competition/predation from nonnative species, and biocontaminants. Many nonnative species have been intentionally introduced into impoundments and have found their way into the river reaches. The most troublesome species were not intentionally introduced into the river but have invaded from other sources. Invading channel catfish, northern pike, striped bass (seasonal runs), red shiner, and common carp exacerbate the recovery effort in the river reaches. Researchers indicate that nonnative species dominate catches in the rivers with red shiner being the most numerous species. Adult forms of these species may prey on native fish while the juvenile and larval stages compete for limited food and habitats. The Colorado River supports more native fish species and numbers than the other tributaries into Lake Powell. Regulated river flows minimize natural extremes in flow which allows nonnative fish to occupy habitats which otherwise would not be suitable for them.

2. Goal for Rivers: To protect, restore and recover, where possible, native fish populations, particularly threatened and endangered fishes endemic to the Colorado River Basin, within Glen Canyon NRA.

3. Flowing River Management Objectives

a. Understand native fish habitat requirements and life history.

b. Ensure that optimum instream flow regimes required for native fish recovery are maintained.

c. Conserve native fish populations while maintaining genetic integrity.

d. Understand natural reproduction requirements and impediments of native species survival.

e. Identify limitations to recruitment of all life stages of native fish.

f. Establish benchmark or reference sites to monitor population trends and assess impacts from dam operations.

g. Identify and prevent pathogens, parasites, and invading organisms from negatively impacting fisheries and monitor fish health.

h. Assess contaminant levels in fish and aquatic food chain organisms; identify sources and protective measures.

i. Explore measures to control nonnative fish populations when they negatively influence native fish.

j. Promote recreational harvest of sport fish in flowing rivers.

B. INFLOWS

1. Status of Inflows: Inflows are artificially created habitats formed as a result of the dam backing up waters of Lake Powell. They are the most productive aquatic habitats within the Glen Canyon NRA and support the greatest fish biomass. The inflow estuary is a bountiful nursery area for young fish and for planktivorus adults. Inflowing rivers carry a nutrient load and naturally occurring trace elements with the sediment that are

deposited at the inflow. The nutrient rich waters allow development of huge plankton blooms where silt deposition allows sufficient sunlight penetration. Trace elements are incorporated into the food chain via plankton. Food chain organisms containing selenium at levels of 3 ug/g dry weight or more should be viewed as potentially detrimental to aquatic organisms that consume them. Plankton collected by NPS in 1994 at Lake Powell inflows ranged from <0.05 to 6.0 ug/g dry weight selenium. Water clarity is highly variable depending on precipitation, snow melt runoff, and flood events. Inflows act as mixing zones between river and reservoir where native species from river habitats commingle with nonnatives from the reservoir habitats. Larval drift of native fishes spawned upstream in flowing rivers deliver early life stages to the inflows. It is likely that conditions favoring predators occur often enough to negatively impact growing young native fish attempting to survive in the inflow. Native fish presumably need timely access to river habitat to avoid predation from fish assembled in the inflow.

Critical habitat has been designated within Glen Canyon NRA for endangered fish and encompasses inflow reaches of Lake Powell, both on the Colorado and San Juan rivers, including the upper San Juan Arm of Lake Powell to Neskahi Canyon, and Colorado River to North Wash (USFWS, Federal Register 4/94). The intent of designating these sometimes flat water reaches of Lake Powell as critical habitat was to insure that inflow areas would be included annually at any lake level. At the lake's lowest projected water level the San Juan inflow may be found near Neskahi Canyon and at that level habitat critical to the survival of endangered fish may extend to Neskahi Canyon.

While nonnative fish dominate the biomass of fish in the inflow areas, recent investigations have revealed the presence of Colorado squawfish and razorback suckers in lake inflow reaches. Young-of-year squawfish frequent the Colorado River inflow in most years, however, they are more numerous in the spring and appear to successfully overwinter or continually migrate downstream through the winter. Pre-runoff surveys conducted by BIO/WEST, Inc. in April 1993, found 101 squawfish in the Colorado River inflow reach of Glen Canyon NRA, but in the fall post runoff survey in August, only 3 squawfish were encountered. Fry, spawned in the river in mid-summer, drift with the current until they settle out in backwaters or the inflow area. Less squawfish at the inflow in the fall suggest young fish either moved back upstream when the current lessened or were heavily cropped by predation in the inflow area. In the Colorado River inflow, it appears that squawfish may be able to overwinter, but no overwinter survival has yet been documented in the San Juan Arm of Lake Powell. In 1994 UDWR found two squawfish that survived over winter below Grand Gulch.

A tagged adult squawfish captured in the San Juan inflow and released at point of capture was recaptured 7 months later in the San Juan River near Bluff, Utah. This has been the only documented case of squawfish movement between Lake Powell and the San Juan River. Another documented case of squawfish movement from Lake Powell to the Grand Junction area occurred in 1981-82 by USFWS. The number of squawfish frequenting the Colorado inflow greatly exceeds those found at the San Juan inflow.

When the lake first filled, sediment was deposited in the braided channel of the San Juan river near Paiute Farms Wash. As lake elevation receded from full pool, the San Juan River cut a new course through the sediment and over a rock ledge which became a waterfall of about 25 feet in height near Paiute Farms. The waterfall created a temporary barrier to fish passage upstream from Lake Powell into the San Juan River in the late 1980's and early 1990's. While the waterfall hindered upstream invasion of nonnative fish into the flowing San Juan River (a benefit to natives in the river), it also precluded upstream migration of YOY, or adult native fish (a liability to recruitment of natives). The waterfall also acted as a dam by reducing the river gradient. The waterfall was inundated by the filling lake in 1995 and the migration barrier was eliminated. Recent surveys suggest that there may have been an influx of nonnatives moving above the recently covered waterfall. The waterfall may reappear as lake levels decline in the future.

The number of razorback suckers found in the Glen Canyon NRA in recent years has declined dramatically. A few adult razorback suckers were removed from the inflow reach of the San Juan River in the late 1980's and early 1990's. These fish are being held in hatcheries as broodstock. Recent surveys for adult razorback suckers have been unsuccessful, with the exception of one experimentally stocked, radio-tagged razorback sucker that was captured by NBS/BOR/NPS joint survey efforts (March '95) in the San Juan inflow. Numbers of razorback suckers in Lake Powell, the inflows, and the San Juan River appear to be at all time lows.

The fluctuating nature of Lake Powell greatly influences the location of inflow, backwaters and/or habitat available. When the lake level is full, or nearly so (3690 to 3700 feet), there are no backwater habitats below Clay Hills Crossing on the San Juan or few above Hite on the Colorado. However, when lake levels are low, there can be several miles of river that may have slackwater or backwater habitats to provide nursery habitat for native fish below Clay Hills or Hite. The amount and rate of water released from the dam plays an important role in determining the quality and amount of certain types of habitat available for fish in the entire lake.

2. Inflow Goal: To protect and restore native fish populations, particularly threatened and endangered fishes endemic to the Colorado River Basin.

3. Inflow Management Objectives

a. Understand needs of native fish and enhance survival.

b. Assess impact of dam operation on native fish habitat and survival.

c. Quantify habitat at varying lake levels.

d. Assess impact of predation on YOY natives at inflow.

e. Evaluate habitat use and timing by fry and other life stages that may use the inflow on a seasonal basis.

f. Quantify native fish population size and structure.

g. Understand and assess contaminant levels in fish and sediment.

h. Understand the role of migration barriers to fish movements.

i. Investigate movement patterns, habitat utilization, and species interactions in the inflows.

j. Provide the opportunity for hatcheries to stock surplus native fish in the critical habitat reaches at inflows.

C. LAKE POWELL

1. Status of Lake Powell: Lake Powell's size, grandeur, and location make it a destination stop for residents of surrounding states and visitors from all over the U.S. and many foreign lands. Over 3 million people visit Glen Canyon NRA annually and those that fish exert close to 2 million angler hours in pursuit of a wide variety of sport fish. Over the life of the reservoir, anglers have caught one fish for every two hours fished. As angling pressure has increased, catch rate has declined. Currently, the catch rate is near 0.3 fish per hour. About half

the fish caught are harvested, resulting in an average harvest of 300,000 fish annually. The native Colorado River fishes have not fared well in the reservoir environment dominated by nonnative predators. While some native species may spawn within the reservoir and others have young that drift into the lake, predation is believed to eliminate young native fish from the reservoir and precludes their survival/recruitment.
The biggest sport fisheries management challenge is trying to stabilize a striped bass population that reproduces without limits and decimates pelagic stocks of threadfin shad upon which they depend. Elimination of shad results in striped bass starvation. Reduction of striped bass numbers allow shad to rebound from adult stocks residing in turbid, thermal refuges where they are less vulnerable to striped bass predation. As shad reenter the pelagic zone in large numbers, they are eaten by young stripers who grow rapidly, mature, and then, once again, eliminate shad from the pelagic zone. This classic predator-prey cycle fluctuated wildly during the 1980's and still occurs at present but within narrower parameters. Threadfin shad in Lake Powell exist in the northern most portion of their range. Lower lethal temperatures for shad are reported as 4.5-5° C. Shad currently survive winters where water temperatures consistently range near the lethal limit by seeking deep strata where temperature is stable without sudden changes that could trigger massive shad mortality. A reduction of even 1° C. may remove the shad thermal refuge and result in loss of shad over winter. Any proposal to alter dam operations, such as a multilevel intake structure that could alter the lake heat budget, must be evaluated with the potential loss of shad in mind. The absence of a pelagic forage fish would be devastating to Lake Powell sport fisheries. The absence of shad would not eliminate striped bass which now reproduce without limit and subsist on plankton for the first year or two of life. The end result would be a permanently stunted striped bass population without quality sport fishing value that may exert extreme predatory pressure on plankton abundance and thereby negatively impact other Lake Powell fishes.

Results of recent NPS and USFWS surveys indicate some biocontaminants show an increasing trend in aquatic organisms nearing the dam. Selenium in plankton from Wahweap Bay and Warm Creek ranged 5.3 to 14.6 ug/g dry weight. Striped bass filets taken in Warm Creek and near the dam contained 12.7 to 19.9 ug/g dry weight selenium. Although there has been no apparent negative impacts on reproduction or survival of striped bass themselves, selenium at these levels could pose potential problems to anglers. Removal of angler catch limits of striped bass as a means of reducing that species has increased the opportunity for anglers to take and consume large quantities of fish filets containing selenium. Educating anglers and involving public health officials in risk assessment for developing consumption advisories is recommended, if determined that they are needed.

2. Lake Powell Goal: Maintain a stable, balanced sport fishery.

3. Lake Powell Management Objectives

   a. Provide sport fisheries with an average catch rate of 0.5 fish/hour for all species combined.

   b. Maintain the following average sizes for sport-caught fish as identified in the UDWR Lake Powell Water Management Plan:

Species	Average size	Size range (inches)
Largemouth bass	12	(8-15)
Smallmouth bass	11	(7-14)
Striped bass	18	(12-19)
Walleye	14	(10-16)
Channel catfish	12	(9-15)
Bluegill	7	(5-9)
Black crappie	9	(7-11)

   c. Provide an average catch rate of 0.05 striped bass/hr for trophy sized fish (>20 inches).

   d. Maintain or enhance forage conditions to allow adequate nutrition of all fish in Lake Powell.

   e. Promote and regulate sport fisheries to ensure that they are protected, utilized, and harvested to provide maximum recreational angling opportunity while maintaining balance among species.

   f. Monitor annual trends in relative abundance of Lake Powell fishes and annual production and recruitment to determine current state of fisheries and define future direction of management programs.

   g. Gain knowledge of striped bass population dynamics which could then be used to keep the population in balance with other species and changing environmental conditions.

   h. Develop consistent basic yield fisheries with a minimum of cyclical swings in fish abundance and physical condition.

i. Maintain a stable black bass fishery comprised of both largemouth and smallmouth bass.

j. Balance the striped bass fishery by providing an abundant angler harvest of healthy basic yield size fish while maintaining a consistent trophy sized component.

k. Promote complementary seasonal fisheries that add variety to the Lake Powell experience and encourage a wide variety of anglers to participate and then return to try it again.

l. Optimize angler opportunities to harvest striped bass.

m. Maintain static or rising lake level from April 1 to June 15 each year.

n. Promote angler harvest of carp, catfish, and walleye.

o. Provide aquatic habitats with ample vegetative cover to improve nursery habitat.

p. Assess contaminant levels in Lake Powell fish tissues.

q. Understand and minimize the impacts of dam operation on native and sport fish populations.

D. LEES FERRY TAILWATER

1. Status of Lees Ferry Tailwater: The 15-mile tailwater below Glen Canyon Dam is known as the Lees Ferry reach. The tailwater is completely controlled by releases from Glen Canyon Dam. Dam release patterns have been shown to influence the aquatic food chain and the overall health of trout. Flows from Glen Canyon Dam are currently being maintained under interim flow restrictions. Under these flows the food base has stabilized and trout condition is improving. Many anglers utilize catch and release techniques. Most of the trout taken are under the slot limit. Trout in the 16-22 inch slot limit must be returned alive. The largest remnant population of humpback chub resides in the Little Colorado River downstream from Glen Canyon NRA. Within Lees Ferry tailwater, the flannelmouth sucker, bluehead sucker, and speckled dace are native fish that are still found in the altered river habitat.

2. Lees Ferry Tailwater Goal: Maintain a "blue ribbon" trout fishery in the altered river habitat by regulations emphasizing

limited harvest. Protect and restore those native fish that still reside in this reach.

3. Lees Ferry Tailwater Management Objectives

   a. Conserve and restore the native fish community in Glen Canyon while providing for coldwater sportfish populations and recreational opportunities.

   b. Maintain healthy, self-sustaining populations of flannelmouth sucker, bluehead sucker, and speckled dace in the mainstem Colorado River in Grand Canyon and its tributaries.

   c. Recreational fishing is to be used as a tool to reduce or control nonnative species.

   d. Maintain and enhance the aquatic food base in Glen Canyon. Maintain continuously inundated areas of *Cladophora* and aquatic invertebrates at or above 5,000 cfs discharge.

   e. Establish and maintain a trophy trout fishery in Lees Ferry reach of Glen Canyon.

   f. Rainbow Trout Age III fish should be at least 50% from natural reproduction.

   g. Maintain spawning habitat.

   h. Maintain estimated population of Age II and older fish at or above 100,000 fish.

   i. Growth rates such that Age III rainbow trout achieve 18" in length, and relative weight of at least 0.80.

   j. Protect existing population of flannelmouth sucker.

   k. Protect spawning location at Paria confluence.

   l. Study habitat needs and movement of flannelmouth suckers.

   m. Determine factors limiting recruitment of young flannelmouth suckers.

   n. Determine the effects of dam operations on native and nonnative fish.

E. PERENNIAL/INTERMITTENT STREAMS

1. Status of Fisheries in Streams: Most streams in side canyons have not had surveys conducted to determine the status of fisheries. Streams connected with Lake Powell (below full pool elevation of 3700) are subject to periodic inundation and potential invasion by all species present in the reservoir. Management efforts stated in this section will focus on streams above Lake Powell full pool elevation, particularly emphasizing streams isolated from the lake.

2. Stream Goal: Protect and preserve native species and habitats in streams and isolated springs.

3. Stream Management Objectives

   a. Protect water quality, water sources, and instream flows in streams and isolated aquatic habitats.

   b. Maintain native assemblages in streams.

   c. Understand and protect unique isolated aquatic ecosystems within Glen Canyon NRA.

   d. Conduct aquatic inventories of perennial streams.

   e. Prevent introduction of nonnatives in streams.

   f. Develop a stream survey plan.

V. PLAN IMPLEMENTATION

A. PLAN REVIEW AND RENEWAL: This Fish Management Plan will remain in effect for 5 years and will be reviewed annually at the Annual Fish Management Workplan meeting by representatives from UDWR, AGFD and Glen Canyon NRA. This plan may be renewed for 5 years upon written agreement of the agencies.

B. ANNUAL WORKPLAN MEETINGS: Representatives from UDWR, AGFD and Glen Canyon NRA will meet each December to approve the upcoming year's annual (1 January - 31 December) fish management workplan for Glen Canyon NRA. This meeting will be chaired on a rotating basis. The purpose of this meeting will be to 1) complete annual review of the FMP, 2) review the previous year's work, 3) insure that workplans and proposals submitted by the three agencies and/or outside agencies, organizations, or non-agency researchers are in conformance with the FMP, 4) coordinate any required permitting by UDWR, AGFD and NPS and 4) approve a mutually agreed upon written annual workplan for the upcoming year.

Annual workplanning will create opportunities to share resources, avoid duplication, increase efficiencies, and identify needed activities to accomplish the objectives of the FMP.

C. WORKPLAN DEVELOPMENT: Agency workplans and/or proposals and non-signatory proposals received by the agencies will be distributed 30 days prior to the annual workplan meeting to allow sufficient time for review.

Proposals will conform to the Glen Canyon NRA "Guidelines and Standards for Obtaining Research/Study Permits and Preparing and Submitting Study Proposals", UDWR Certificate of Registration (COR) requirements and/or AGFD proposal guidelines.

Permits from UDWR, AGFD, Glen Canyon NRA, and USFWS must be obtained as necessary by the agency carrying out the planned activity. Activities by AGFD, UDWR, and Glen Canyon NRA requiring permits may receive such permits from the respective state or Glen Canyon NRA if the proposed activity is in the approved annual work plan. Permits for other entities will be processed by the effected agencies with the understanding that such permits may only be issued for activities identified in the annual work plan.

D. WORKPLAN APPROVAL: The UDWR Lake Powell Project Manager, AGFD Fisheries Branch Supervisor, and the Chief of Resource Management at Glen Canyon NRA will approve the annual work plan. The annual work plan can be amended during the calendar year by written agreement among these three approving officials.

E. DATA SHARING: The UDWR, AGFD, and Glen Canyon NRA agree to share data regarding fishery and aquatic resources as well as data related to visitor demographics and use and protection of fishery resources. The agencies will seek out cooperative efforts for data collection, storage, sharing, and dissemination.

VI. EDUCATION/PUBLIC OUTREACH

The purpose of the education outreach program is to expand information transfer, enhance community support, and develop learning programs about Glen Canyon NRA aquatic resources and fisheries. The cooperating agencies participate in the following types of activities.

A. INTERPRETIVE PROGRAMS: NPS interpretive rangers give evening programs which include topics on Lake Powell water quality, historical pre-dam ecology, and current status of aquatic ecology and fisheries. Fishing workshops and demonstrations may be scheduled, particularly during National Fishing Week.

B. HOTLINE: UDWR offers a toll-free telephone number (1-800-ASK-FISH) with recorded information updated weekly to direct anglers to the best fishing areas. Tips on fishing techniques, effective tackle, and species availability are provided so visitors can call ahead to plan and optimize angling success.

C. DISPLAYS AND BROCHURES: Interpretive and informative displays near launch ramps and in visitor centers increase awareness of fishing rules, opportunities, and some issues, such as the declines of native species. Brochures are available from NPS to acquaint visitors to fishing opportunities, fish species present, and current regulations. UDWR Fishing Proclamation and Arizona Fishing regulations are available at visitor centers and at local businesses where license and tackle are sold.

D. VIDEOS: Development of action videos will be encouraged to promote recreational fishing. Informative videos should also be developed to introduce visitors to native and endangered fish species. Educational videos could be made available to schools and other organizations, to include career opportunities and issues related to aquatic ecology, water quality, and fisheries.

E. PARTNERSHIP WITH SCHOOLS: Increasing interaction with local schools would be of benefit to students as well as promote environmental awareness and resource stewardship. Teachers and fishery managers can develop curriculum and study projects to give students skills and information that would be interesting and useful both during classroom and while recreating within Glen Canyon NRA. Cooperative education opportunities, such as "stay-in-school" and work-study programs, will offer students hands-on experience. Cooperative programs with colleges and universities will provide students an opportunity to complete needed research for management agencies.

APPENDIX A: STOCKING HISTORY OF LAKE POWELL, UTAH-ARIZONA, 1963-1995.

Year	Species	Number	Size	Area	Method
1963	Largemouth Bass	924,000	2-3"	Warm Creek-Aztec	Aerial
	Rainbow Trout	3,000,000	2"	Reservoir Wide	Aerial
	Rainbow Trout	800,000	2-4"	Wahweap Creek	Truck
	Rainbow Trout	35,000	4"	Halls Crossing	Truck
	Kokanee Salmon	600,000	1-2"	Kane Creek	Truck
1964	Largemouth Bass	1,000,000	2-3"	Wm Crk-Last Chance	Aerial
	Largemouth Bass	250,000	2-3"	Mouth Escalante	Aerial
	Largemouth Bass	250,000	2-3"	Rincon	Aerial
	Largemouth Bass	500,000	2-3"	Bullfrog Creek	Aerial
	Rainbow Trout	3,000,000	2-3"	Dam-Bullfrog Creek	Aerial
	Rainbow Trout	325,650	5-8"	Hite	Truck
	Rainbow Trout	365,730	5-8"	Wahweap Creek	Truck
	Kokanee Salmon	35,000	2-3"	Wahweap Creek	Truck
	Black Crappie	350	6"	Wahweap Creek	Truck
	Black Crappie	9,000	3"	Wahweap Creek	Truck
1965	Rainbow Trout	4,383,525	2-3"	Reservoir Wide	Aerial
	Rainbow Trout	40,000	5"	Wahweap Creek	Truck
	Black Crappie	30,000	1"	Wahweap Creek	Truck
	Black Crappie	4,700	4"	Wahweap Creek	Truck
1966	Rainbow Trout	2,140,000	2-3"	Reservoir Wide	Aerial
1967	Rainbow Trout	344,049	4-5"	Wahweap-Warm Creek	Aerial
	Rainbow Trout	103,205	4-5"	Halls -Bullfrog	Barge
	Rainbow Trout	102,590	4-5"	Red Canyon	Barge
1968	Rainbow Trout	201,364	3-5"	Wahweap Creek	Barge
	Threadfin Shad	1,500	1-4"	Wahweap Creek	Truck
1969	Rainbow Trout	251,238	5"	Wahweap Creek	Barge
	Threadfin Shad	200,000	Egg-fry	Wahweap Creek	Spawn mats
1970	----------NO STOCKING----------				
1971	Rainbow Trout	281,000	4-5"	Bullfrog	Barge
	Rainbow Trout	527,000	4-5"	Wahweap Creek	Barge
	Rainbow Trout	40,000	4-6"	Warm Creek	Barge
1972	----------NO STOCKING----------				
1973	Rainbow Trout	233,400	5"	Wahweap Creek	Truck
1974	Striped Bass	49,885	2-3"	Wahweap Creek	Truck

APPENDIX A: Continued

Year	Species	Number	Size	Area	Method
1975	Striped Bass	94,878	2-3"	Wahweap Creek	Truck
1976	Rainbow Trout	50,000	3-6"	Wahweap Creek	Truck
	Striped Bass	35,752	2-3"	Wahweap Creek	Truck
	Striped Bass	19,305	2-3"	Bullfrog	Aerial
1977	Rainbow Trout	18,600	5"	Wahweap Creek	Truck
	Striped Bass	86,003	2-3"	Wahweap Creek	Truck
	Striped Bass	52,650	2-3"	Bullfrog	Aerial
1978	Striped Bass	169,469	2-3"	Wahweap Creek	Truck
	Striped Bass	84,821	2-3"	Bullfrog	Aerial/Truck
1979	Striped Bass	222,550	2-3"	Wahweap Creek	Truck
1980	Rainbow Trout	13,210	6"	Wahweap Creek	Truck
1981----------------------------NO STOCKING--------------------					
1982	Smallmouth Bass	3,100	2-4"	Warm Creek	Truck
	Smallmouth Bass	59	10-15"	Warm Creek	Truck
1983----------------------------NO STOCKING--------------------					
1984	Smallmouth Bass	26,600	2-4"	Wahweap-Warm Creek	Truck
	Smallmouth Bass	4,000	2-4"	Stanton Creek	Aerial
1985	Smallmouth Bass1	3,289	2-4"	Wahweap Creek	Truck
	Smallmouth Bass	12,389	2-4"	Antelope Canyon	Truck
	Smallmouth Bass	22	10-15"	Antelope Canyon	Truck
	Smallmouth Bass	31,995	2-4"	Rincon	Aerial
	Smallmouth Bass	19,390	2-4"	Good Hope Bay	Aerial
	Smallmouth Bass	26,328	2-4"	Neskahi Canyon	Aerial
	Smallmouth Bass	702	10-15"	Hite-Dirty Devil	Truck
1986	Smallmouth Bass	12,758	2-4"	Escalante River	Aerial
	Smallmouth Bass	8,136	2-4"	Paiute Farms Wash	Truck
	Smallmouth Bass	6,123	2-4"	Wahweap Creek	Truck
1987	Smallmouth Bass	220	3-6"	Wahweap-Warm Creek	Truck
	Smallmouth Bass	24,200	2-3"	West Canyon	Aerial
	Smallmouth Bass	7,200	2-3"	Nokai Canyon	Truck
		3,150	2-4"	Paiute Farms	Truck
1988	Smallmouth Bass	20,536	2"	Knowles/Cedar Canyon	Aerial
	Smallmouth Bass	24,643	2"	Llewellyn/Cottonwood	Aerial
	Smallmouth Bass	4,307	2"	Middle Rock Creek	Aerial
	Smallmouth Bass	10,745	2"	San Juan (mouth)	Aerial
	Smallmouth Bass	10,800	2"	Navajo Canyon	Aerial
1989	Smallmouth Bass	21,002	2"	Trachyte Canyon	Aerial
	Smallmouth Bass	2,394	2"	Warm Creek (mouth)	Boat

APPENDIX A: Continued

Year	Species	Number	Size	Area	Method
1990	------------- NO STOCKING --------------------------------				
1991	------------- NO STOCKING --------------------------------				
1992	Black Crappie	7,000	2"	Warm Creek	Truck
1993	Black Crappie	10,000	2"	Wahweap Bay	Truck
1994	------------- NO STOCKING --------------------------------				
1995	------------- NO STOCKING --------------------------------				

APPENDIX B: STOCKING HISTORY OF LEES FERRY TAILWATER

Stocking History of Lees Ferry 1978-1995 in Thousands of Trout

YEAR	RAINBOW*	BROOK	CUTTHROAT	TOTAL
1978	50	200	60	310
1979		43		43
1980	15	40	1	56
1981	108	60		168
1982	50			50
1983	99	50		149
1984	128			128
1985	121	50		171
1986	128	40		168
1987	121	25		146
1988	150			150
1989	129			1[illegible]3
1990	61			61
1991	72			72
1992	78			78
1993	73			73
1994	103			103
1995	73			73

*including kamloops 1985 - 60, 1986 - 34, 1987 - 21, 1988 - 66

APPENDIX C: FIGURE 1 (MAP) GLEN CANYON NRA, INCLUDING LAKE POWELL AND MAJOR TRIBUTARIES

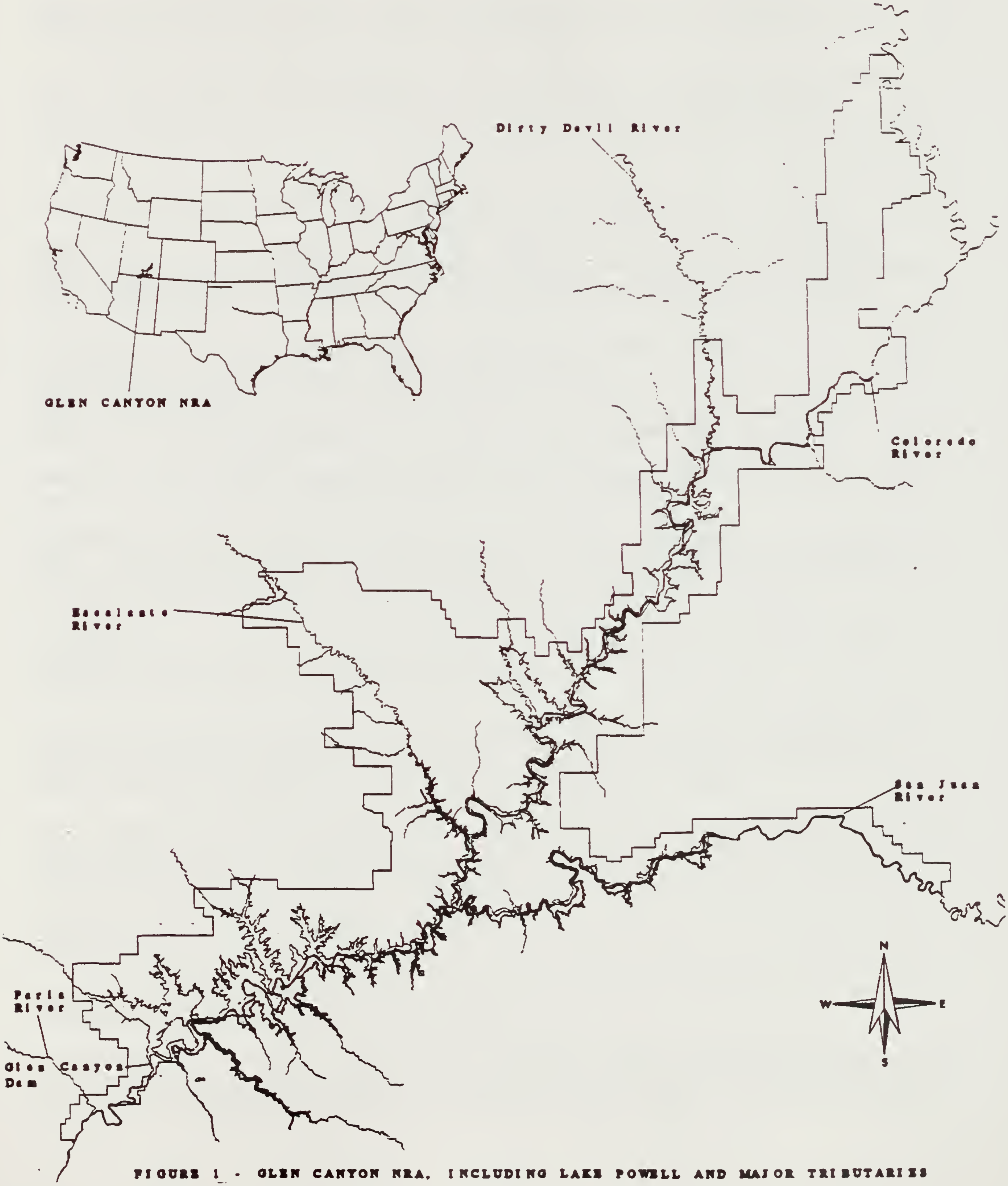


FIGURE 1 - GLEN CANYON NRA, INCLUDING LAKE POWELL AND MAJOR TRIBUTARIES

BIBLIOGRAPHY

Anderson, R. O. 1973. Application of theory and research to management of warmwater fish populations. Trans. Am. Fish. Soc. 102(1):164-171.

Behnke, R.J. and D.E. Benson. 1980. Endangered and threatened fishes of the Upper Colorado River Basin. Cooperative Extension Service, Colorado State University, Fort Collins. Bulletin 503A. 34 pp.

Berg, L. N. and A. W. Gustaveson. 1992. Results of the 1991 creel survey conducted at Lake Powell compared to previous years. Project F-46-R. Publication No. 92-10. Salt Lake City, Utah Division of Wildlife Resources. 24 pp.

Bestgen, K. R. 1990. Status review of the razorback sucker. Contribution 44, Colorado State Univ. Larval Fish Lab. Fort Collins, CO. 92 pp.

Bozek, M. A., L. J. Paulson, and J. E. Deacon. 1984. Factors affecting reproductive success of bonytail chubs and razorback suckers in Lake Mohave. Tech. Rept. No. 12. USFWS Contract No. 14-16-0002-81-251. Univ. NV Las Vegas. Las Vegas, NV.

Carlander, K. D. 1977. Handbook of freshwater fishery biology. Vol. I. The Iowa State University Press. Ames, Iowa. 431 pp.

Combes, D. L. 1978. Food habits of adult striped bass from Keystone Reservoir and its tailwaters. Proc. Ann. Conf. SEAFWA 32:571-575.

Fedoruk, A. N. 1966. Feeding relationship of walleye and smallmouth bass. Journal of Fishery Research Board of Canada 23:941-943.

Gustaveson, A. W., T. D. Pettengill, M. J. Ottenbacher, and J. E. Johnson. 1980. Lake Powell Fisheries Investigations. 5-year completion and 1979 Annual Performance Report. Dingell-Johnson Project F-28-R-8. Publi. No. 80-11. Salt Lake City, Utah Division of Wildlife Resources. 75 pp.

Gustaveson, A. W., T. D. Pettengill, J. E. Johnson and J. R. Wahl. 1984a. Evidence of In-reservoir spawning of striped bass in Lake Powell, UT-AZ. North Am. Jour. Fish. Management 4:540-546.

Gustaveson, A.W., B.L. Bonebrake, S.J. Scott and J.E. Johnson. 1985. Lake Powell fisheries investigations. 5-year Completion and 1984 (Segment 13) Annual Performance Report. Dingell-Johnson Project F-28-R. Publi. No. 85-12. Salt Lake City, Utah Division of Wildlife Resources. 73 pp.

Gustaveson, A. W., H. R. Maddux, B. L. Bonebrake, and K. Christopherson. 1990. Lake Powell Fisheries Investigations, 5-year completion and 1989 Annual Performance Report. Dingell-Johnson Project F-46-R. Salt Lake City, Utah Division of Wildlife Resources. 67 pp.

Hamman, R. L. 1982. Spawning and culture of humpback chub. Prog. Fish-Cult 44|213-216.

Hamman, R.L. 1985. Induced spawning and culture of hatchery-reared bonytail. Progressive fish-Culturist 47(3):239-241.

Heidinger, R. C. 1983. Life History of gizzard shad and threadfin shad as it relates to the ecology of small lake fisheries. Pages 1-18 in Proceedings of Small Lakes Management Workshop - "Pros and Cons of Shad." Iowa Conservation Commission and Sport Fishing Institute, Des Moines, IA.

Jonez, A. and R. C. Sumner. 1954. Lake Mead and Mohave Investigations. D. J. Project F-1-R. Nevada Fish and Game Commission. 186 pp.

Lanigan, S.H., and H.M. Tyus. 1989. Population size and status of the Razorback sucker in the Green River, Utah and Colorado. N. Amer. J. Fish. Mgmt., 9:68-73.

McAda C.W. 1978. Aspects of the life history of three catastomid's native to the upper Colorado River basin. Thesis Utah State University. 105 pp.

McCarthy, M.S., and W.L. Minckley. 1987. Age estimation for razorback sucker (Pisces:Catostomidae) from Lake Mohave, Arizona and Nevada. J. Arizona-nevada Acad. Sci., 21:87-97.

Minckley, W. L. 1983. Status of razorback sucker in the lower Colorado RIver. Southwest Naturalist 28(2):165-187.

Minckley, W.L. 1985. Native fishes and natural aquatic habitats in U.S. Fish and Wildlife Service Region II, west of the Continental Divide. U.S. Department of the Interior, Fish and Wildlife Service, Division of Endangered Species, Albuquerque, New Mexico. 158 pp.

Minckley, W.L., P.C. Marsh, J.E. Brooks, J.E. Johnson and B.L. Jensen. 1991. Management toward recovery of the razorback sucker. Pp. 303-357, in Battle against extinction: native fish management in the American west. (W.L. Minckley and J.E. Deacon, eds.). Univ. Ariz. Press, Tucson, Arizona, 517 pp.

Morris, D. J. and B. J. Follis. 1978. Effects of striped bass predation upon shad in Lake E. V. Spence, TX. Proc. Annu. Conf. SEAFWA 32:697-702.

Mraz, D. 1964. Observations on large and smallmouth bass nesting and early life history. Research Report No. 11 (Fisheries). Wisconsin Conservation Department. 13 pp.

Mueller, Gordon, 1995. A Program for Maintaining the Razorback Sucker in Lake Mohave. American Fisheries Society Symposium 15:127-135.

Mueller, G., M. Horn, J.Krahl, Jr., T. Burke, and P. Marsh. 1993. Use of larval light traps to capture razorback sucker *(Xyrauchen texanus)* in Lake Mohave, Arizona-Nevada. The Southwestern Naturalist 38:399-402.

Muth, Robert T., 1995. Summary of Collections Made in 1994 as a Part of the Larval Razorback Sucker Survey Project, Green and Colorado Rivers in Canyonlands National Park and Colorado Inflow to Lake Powell in Glen Canyon National Recreation Area, Utah. Larval Fish laboratory, Colorado State University.

Nash, V. S., W. E. Hayes, R. L. Self, and J. P. Kirk. 1987. Effect of striped bass introduction in Lake Wateree, South Carolina. Proc. Annu. Conf. SEAFWA 41:48-54.

Parsons, W. R., and J. B. Kimsey. 1954. A report on the Mississippi threadfin shad. Prog. Fish-Cult. 16(4):179-181.

Persons, W. R., R. V. Bulkley, and W. R. Noonan. 1981. Movements and feeding of adult striped bass, Colorado River inlet, Lake Powell, 1980-81. Utah Coop. Rish. Res. Unit. Logan UT. 30 pp.

Schaich, B. A. 1979. A biotelemetry study of spring and summer habitat selection by striped bass in Cherokee Res., TN 1978. M. S. Thesis. Univ. of TN, Knoxville, TN. 206 pp.

Scott, S. J. and A. W. Gustaveson. 1989. A creel census summary of twenty-two years at Lake Powell, Utah 1964-1985. Project F-46-R. Publication No. 89-10. Utah Division of Wildlife Resources. Salt Lake City, Utah. 32 pp.

Sigler, W.F. and R.R. Miller. 1963. Fishes of Utah. Utah State Dept. Fish and Game, Salt Lake City, Utah. 203 pp.

Sigler W.F., and J.W. Sigler 1987. Fishes of the Great Basin a natural history. Reno: University of Nevada Press.

Tyus, H.M. 1987. Distribution, reproduction, and habitat use of the razorback sucker in the Green River, Utah, 1979-1986. Trans. Amer. Fish Soc., 116:111-116.

Tyus, H.M. and W.L. Minckley. 1988. Migrating Mormon crickets, _Anabrus simplex_ (Orthoptera: Tettigigoniidae) as food for stream fishes. Great basin Nat. 40(1):

Tyus, H.M. and C.A. Karp. 1990. Spawning and Movements of razorback sucker,(_Xyrauchen texanus_), in the Green River basin of Colorado and Utah. Southwestern Nat., 35:427-433.

U.S. Fish and Wildlife Service. 1990. Colorado Squawfish Recovery Plan. U.S. Fish and Wildlife service, Denver, Colorado. 56 pp.

U.S. Fish and Wildlife Service. 1990. Humpback Chub Recovery Plan. U.S. Fish and Wildlife service, Denver, Colorado. 43 pp.

U.S. Fish and Wildlife Service. 1990. Bonytail Chub Recovery Plan. U.S. Fish and Wildlife service, Denver, Colorado. 35 pp.

Utah Division of Wildlife Resources. 1992. A strategic plan for the comprehensive management of Utah's wildlife resources. UT Div. of Wildlife Resources, Slat Lake City, UT. 249 pp.

Valdez, R. A. 1990. The endangered fish of Cataract Canyon. Final Report prepared for the U S Department of Interior, Bureau of Reclamation, Salt Lake City, Utah. Contract No. 6-CS-40-03980, Fisheries Biology and Rafting. Bio/West Report No. 134-3. 94 pp + appendices.

Valdez,R.A and B.R. Cowdell. 1994. Lake Powell Inflow Study. Annual Summary Report-1993. Prepared for Utah Division of Wildlife Resources, Salt Lake City Utah, Contract No. 90-2558. BIO/WEST Report No. 384-1. 15pp + appendices.

Valdez R.A., and G.H. Clemmer. 1982. Life History and Prospects For Recovery of the Humpback and Bony tail Chub. Pp. 109-119 in Fishes of the Upper Colorado River System: Present and Future.

Valdez, R.A. and L. Lentsch. 1994. The role of Lake Powell in management and recovery of native fishes an information paper.

Vanicek, C.D., and R.H. Krammer. 1969. Life history of the Colorado squawfish Ptychocheilus lucius and the Colorado chub Gila robusta in the Green River in Dinosaur National Monument, 1964-1966. Trans. Amer. Fish Soc., 98:193-208.

Copies of this Fishery Management Plan are available from the following:

National Park Service (520) 608-6200
Glen Canyon National Recreation Area
P.O. Box 1507
Page, Arizona 86040-1507

National Park Service (303) 225-3500
Water Resources Division
1201 Oak Ridge Drive, Suite 250
Fort Collins, CO 80525

National Park Service (303) 969-2130
Technical Information Center
Denver Service Center
P.O. Box 25287
Denver, CO 80225-0287

March 3, 1849

As the nation's principal conservation agency, the Department of the Interior has the responsibility for most of our nationally owned public lands and natural and cultural resources. This includes fostering wise use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people. The Department also promotes the goals of the Take Pride in America campaign by encouraging stewardship and citizen responsibility for the public lands and promoting citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

April 1996